AVIAN RADAR – IS IT WORTH THE COST?

GRADUATE RESEARCH PROJECT

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Abstract

Major Ehasz explored the correlations between bird strike data at United States Air Force (USAF) airfields prior to Avian Radar installation and post Avian Radar installation in order to perform a Business Case Analysis (BCA) to help guide future potential purchases of Avian Radar. He defined the scope of the bird strike problem, explained the associated costs, explored current mitigation efforts leading up to Avian Radar, performed statistical analysis of USAF airfield strike data, and finally suggested additional future solutions for further research. Major Ehasz recommended that all airfields (both civilian and military) recommit to the application of current Air Force Bird/Wildlife Aircraft Strike Hazard (BASH) and Federal Aviation Administration (FAA) guidance in order to obtain proven bird population and bird strike reductions. As a result of this research, Major Ehasz has concluded that existing Avian Radar is not a cost effective method of bird strike reduction, but the USAF should continue to use existing systems for experimentation and collection of further data in order to continue to pursue the technological breakthroughs of tomorrow.

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Bobby Ehasz

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AVIAN RADAR – IS IT WORTH THE COST?

I. Introduction

“So much for the friendly skies - lately it seems like they’re full of angry birds, taking aim at high-ranking officials” (Travers, 2012). On 20 April 2012, the media was plastered with the heading, “Air Force 2 Strikes Bird Upon Landing, Biden Aboard” (Staff, 2012, p. 1). On the very same day, a bird flew into the engine of US Secretary of State Hillary Clinton’s Air Force Presidential fleet aircraft and a third major strike led to the emergency landing of Delta Airlines Flight 1063 returning to John F. Kennedy Airport in New York (Travers, 2012). This might seem like a busy day, but between the years 2006 and 2010, the Federal Aviation Administration (FAA) reported an average of 26 bird strikes per day for civilian airfields and the Air Force Safety Center logged an average of 13 strikes per day for Air Force airfields.

As the media focus on 20 April 2012 illustrates, these bird strikes are not decreasing, but instead, aircraft bird strikes are an increasing problem. Most travelers have no idea how often these scenarios play out. Recently, there have been many strong advances in avian research creating several new ways to mitigate this hazard including Bird Detection Radar (BDR) systems. While these systems have been tested and proven at locating birds, very little research exists to show whether or not an airfield actually benefits from reduced numbers of strikes or reduced costs of strikes after installation of a BDR.

There is one masters paper on this topic titled, “Cost-Benefit Analysis of Bird Avoidance Radar Systems on United States Air Force Installations“ by Major Gavin Gary Gigstead for the Embry-Riddle Aeronautical University, but the overall emphasis is qualitative. Major Gigstead does provide relevant data and presents impressive charts listing costs and total strike numbers, some of which have been used in this study. Without Major Gigstead’s previous work, this research would be impossible. This limited business case study builds on Major Gigstead’s work and applies statistical analysis to quantify the economic justification of further purchases of these systems, or to suggest that these dollars be spent on other more cost effective mitigation efforts.

II. Literature Review

Discussion of the Problem

Ever since the first caveman saw his first bird, humans have desired the ability to fly. As history shows, birds have enjoyed free reign of the skies for 150 million years with powered aircraft and birds sharing the sky for a little over 100 years. Shared skies only become a problem when both humans and birds attempt to occupy the same airspace at the same time causing collisions (Cleary & Dolbeer, 2005).

While 97.2% of aircraft wildlife strikes are due to birds, 2.3% are terrestrial mammals, 0.4% are bats, and 0.1% are reptiles (Dolbeer R. A., Wright, Weller, & Begier, 2012). Very occasionally, deer, coyotes, and alligators wander onto runways and create collision hazards for departing or landing aircraft (Cleary & Dolbeer, 2005). For the purposes of this research, only bird strikes will be considered and a bird strike is defined as a collision between a bird and an aircraft.

Two years after the first aircraft flight in 1903, Orville Wright struck a bird during a flight over a cornfield near Dayton, Ohio (Cleary & Dolbeer, 2005). This first bird strike was the beginning of a long list of famous strikes with reported numbers of military strikes peaking in 2005 with 5,107 strikes (Center, Air Force Safety, 2012). Factors that contribute to this increasing threat are increasing populations of large birds and increasing air traffic by quieter, turbofan-powered aircraft (Dolbeer R. A., Wright, Weller, & Begier, 2012).

Between 1990 and 2010, the FAA wildlife strike database received data for over 121,000 wildlife strikes with 17,605 of these strikes causing damage. For the Air Force,

there have been more than 95,000 reported bird strikes since the Air Force Safety Center began tracking in 1985, with almost 4,500 strikes in 2011 alone (Center, Air Force Safety, 2012). According to the FAA, “Globally, wildlife strikes have killed more than 229 people and destroyed over 210 aircraft since 1988” (Dolbeer R. A., Wright, Weller, & Begier, 2012, p. ix). In addition, the Air Force Safety Center reports 39 aircraft destroyed and 33 deaths on record since 1973 (Center, Air Force Safety, 2012). This loss of human life alone warrants the need for bird strike mitigation efforts, but in order to understand the full scope of this problem all costs must be considered.

Cost Considerations

Of the 17,605 damaging strikes recorded in the FAA database, only 30% provided estimates of aircraft downtime, 17% reported direct costs, and only 8% reported indirect costs. Previous FAA studies conclusively show that on average only 20% of the estimated total damaging strikes from 1990 to 2010 have been reported. By estimating to 100%, “the annual cost of wildlife strikes to the USA civil aviation industry is estimated to be 566,766 hours of aircraft downtime and $677 million in monetary losses” (Dolbeer R. A., Wright, Weller, & Begier, 2012, p. 11). This total breaks down to $547 million per year in direct costs and $130 million per year in associated costs (FAA 2010). The Air Force simply reports direct total costs, such as parts replaced, which still totals approximately $821 million since 1985 (Center, Air Force Safety, 2012).

These totals are significantly underestimated since both civilian and Air Force immediate reporting methods collect the cost data before the total bill is known. Even when the total bill is available, it does not include many hidden costs such as lost

revenue, costs for placing passengers in hotels, re-scheduling aircraft, flight cancellations, lost training, crew shuffling, passenger frustrations, and dumped fuel for emergency landings (Cleary & Dolbeer, 2005).

There are also many indirect costs including man-hours and equipment consumed through bird mitigation efforts already in place at airfields which keep bird strikes at these already reduced levels. Hill Air Force Base (AFB), Utah, recently reported a new United States Department of Agriculture (USDA) wildlife abatement contract costing $155,000 per year. These contracts are not inexpensive, but are one great way for airfields to ensure bird populations remain at a minimum. With the risk to human life and total costs reaching billions of dollars per year, implementing even extremely expensive solutions appears, on the surface, to make good economic sense.

Current Mitigation Efforts

Funding Bird/Wildlife Aircraft Strike Hazard (BASH) teams and USDA abatement contracts appears to be a great mitigation strategy, while not necessarily a complete solution. Civil recorded bird strike data shows that over 74% of collisions occur at or below 500 feet above ground level (AGL) and therefore within the airport environment. For every 1,000-foot gain in height above 500 feet AGL, the number of strikes declined by 33% for commercial aircraft (Dolbeer R. A., Wright, Weller, & Begier, 2012). Of the 19 civil and military large-transport aircraft destroyed by bird strikes from 1960 to 2004, airport environment strikes claimed 18. With the airport environment being suspect in the majority of wildlife strikes, this becomes the logical and easiest place to focus recently constrained resources (Cleary & Dolbeer, 2005).

The first and most important step to mitigation is thorough reporting. Pilots, airport operations personnel, maintainers, and anyone with specific knowledge of a wildlife strike should report. Previous strike data “provides a scientific basis for identifying risk factors; justifying, implementing and defending corrective actions at airports; and judging the effectiveness of those corrective actions” (Cleary & Dolbeer, 2005, p. 6). The next most important step is the FAA mandated wildlife hazard assessment at each individual airfield.

In accordance with Title 14 Code of Federal Regulations, Part 139 Subpart D 139.337(b)(1-4), certified airports are required to complete wildlife hazard assessments when wildlife events occur (Cleary & Dolbeer, 2005, p. 60). The FAA administrator can then determine the wildlife hazard management plan for that particular airfield. These plans will typically include direction to utilize USDA biologists to provide training for airfield personnel in, “wildlife and hazard identification and the safe and proper use of wildlife control equipment and techniques” (Cleary & Dolbeer, 2005, p. 27). The Air Force has a Memorandum of Agreement with the FAA to manage wildlife and to collect strike information in a separate database. This work is accomplished by localized BASH teams.

The Air Force BASH team coordinates all USAF wildlife strike reduction efforts from the Air Force Safety Center Headquarters at Kirtland AFB, New Mexico. The localized Air Force BASH teams utilize Air Force Instruction 91-202 (AFI 91-202) dated 5 August, 2011: *The US Air Force Mishap Prevention Program.* With AFI 91-202, the Air Force strives to reduce aircraft strike hazards in accordance with the FAA four-part

approach including: Awareness, Control, Avoidance, and Aircraft Design (Dolbeer R. A., Wright, Weller, & Begier, 2012).

While three of these: awareness of the problem, controlling populations of birds on the airfield, and aircraft design are critical to BASH programs, this research focuses specifically on methods of bird avoidance. Bird avoidance is a direct result of bird control since the animals needing avoidance are the animals not controlled and therefore are still located on the airfield. Both short-term active and long-term passive techniques are employed to control the airfield and rid the surrounding areas of potential hazards.

If birds still exist after applying these bird control methods, avoidance methods become critical since these birds left on the airfield remain potential bird strikes. This potential was evidenced in 1995 when 22 Americans and 2 Canadians were killed in a USAF E-3 Sentry crashed after it hit a flock of geese on take-off from Elmendorf AFB, Alaska. As a result, in 1996, an unnamed firm and the Air Force worked together to begin baseline testing and bird movement data collection to determine the feasibility of designing an avian radar system to avoid future bird strikes. With this focus on avoidance, the FAA and the Air Force began a collaborative effort to develop a radar system capable of detecting and tracking birds in 2001 (Skudder, 2003). The BDR system was installed at Elmendorf AFB in 2002. However, this system is not currently used for airfield bird collision avoidance but only for migration tracking and is therefore not considered in this study (Air Force Safety Center, personal communication, 2012).

After several Class A and B BASH mishaps, Dover AFB, Delaware, received a BDR in 2006 and has used the device to track bird activity. The base is awaiting official

guidance from the anticipated Air Force Instruction 91-202, expected May 2012, authorizing the use of BDRs for detection of wildlife on the airfield, in real-time. Whiteman AFB, Missouri, received a BDR in 2007 with major upgrades to technology and improved placement location in 2011. Beale AFB, California, and Offutt AFB, Nebraska, both received BDRs in 2008 followed by a combat hardened system at BagramAB, Afghanistan, in 2010 (Air Force Safety Center, personal communication, 2012).

Bird Detection Radar

Using radar technology to locate and track wildlife is not new, but small mobile BDR technology is new. In the developmental days of weather radar, birds were seen as unwanted clutter and a distraction for viewing the weather. With the new understanding that radar can purposely isolate wildlife, several companies have produced commercial systems utilizing combinations of X-band and S-band radar technology solely to identify bird populations on airfields (Sheridan, 2009). Since the 5 Air Force airfields currently utilizing avian radar all employ variations of the MERLIN system, this research focuses solely on this system which is designed and maintained by DeTect, Inc.

The MERLIN radar system has an automatic and distinct advantage over other Air Force systems such as the Low-Level Bird Avoidance Model (BAM) which utilizes historic data to predict bird volume throughout a flight route or the Avian Hazard Advisory system (AHAS) which utilizes weather radar systems to piece together a near real-time image of bird activity (AFPAM 91-212, 2004). Both BAM and AHAS draw information from systems not specifically designed to identify wildlife. BDRs, however,

are designed to eventually provide aircraft controllers or pilots real-time information from a system located on the airfield property focused specifically on locating bird populations and therefore preventing risk at the approach and departure areas of the airfield (Hilkevitch, 2009). This real-time picture of total bird volume in an area should not be confused with a sense-and-alert capability which would allow controllers to vector aircraft around the real-time bird activity. Avian radar is not currently authorized for use as sense-and-alert since technology issues such as delayed reporting and antenna spin rates introduce an unknown volume of error. Real-time bird activity is, however, a huge benefit for USDA officials in locating activity on the airfield to focus immediate control and dispersal strategies (Dolbeer R. A., Wright, Weller, & Begier, 2012).

During operation, these radar systems generate and transmit radio signals capturing the return echo in order to determine the locations of specific targets, in this case wildlife. Since radar provides very limited information such as range, direction, and velocity of target, the digital radar processer is critical in transforming the data into a usable visual display. The radar units are actually the small expense in the overall purchase cost of the radar system (Herricks, Woodworth, & King, 2010). The total costs of all five systems are displayed in Table 1 below. The average maintenance and upkeep costs per year listed in Table 1 include the estimated electrical costs from Table 2 below.

Table 1. Cost Data by AFB (Gigstead, 2011)

Site	Date	Model/Upgrades	Base Cost	Total Equipment Cost	Average Equipment Cost Per Year (From Install)	Total Maintenance and Upkeep Costs (Estimated)	Average Maintenance and Upkeep Costs per Year (Estimated from Install)	Combined Average Cost Per Year (Estimated from Install)
Dover AFB	2006	XS2530i	$310,128					
	2010	2nd VSR & Dual Range Processor	$114,034	$424,162	$70,694	$144,850	$24,142	$94,835
	2011	Extended Warranty (5yrs)	$127,500					
Whiteman AFB	2006	XS5060i	$323,430	$411,470	$68,578	$17,350	$2,892	$71,470
	2010	XS200i-Fixed	$88,040					
Beale AFB	2008	XS2530i	$330,000					
	2010	Extended Warranty (5yrs)	$127,500	$330,000	$82,500	$139,067	$34,767	$117,267
Offutt AFB	2009	XS2530i	$318,000	$318,000	$106,000	$8,675	$2,892	$108,892
Bagram AB	2010	SS200m	$819,837	$819,837	$409,919	$5,783	$2,892	$412,811

Table 2. Estimated Electrical Costs (Gigstead, 2011)

	Equipment Power Consumption (kW)	Number Installed	Total Equipment Power Consumption (kW)	Total Annual Equipment Power Consumption (kWh)	Average Cost of Electricity ($/kWh)	Total Annual Equipment Electrical Cost ($)
Digital Radar Unit	0.20	2	0.40	3,504	$0.10	$350.40
Air Conditioning Unit (5,000 BTU)	1.00	2	2.00	17,520	$0.10	$1,752.00
Desktop Computer	0.15	6	0.90	7,884	$0.10	$788.40
Computer Monitors (sleep mode)	0.0005	2	0.001	8.8	$0.10	$0.88
						$2,891.68

Even though the FAA does not allow see-and-avoid radar use, these very effective radar systems do provide real-time visual displays of birds in the vicinity of the airfield. Existing BDR research has shown that these systems locate birds 97.5% of the time (DeTect, Staff, 2012). However, the focus of this research is to determine if using these systems to identify the locations of the birds actually leads to a reduction in total bird strikes over time for a specific airfield and to determine cost effectiveness of this particular bird avoidance method.

Problem Statement

There is limited quantitative research correlating the average quantity and average cost of bird strikes prior to BDR installation and the average quantity and average cost of bird strikes after BDR installation, on an AF airfield. This research focuses on whether or not BDRs are a cost effective method of bird strike mitigation.

Importance/Relevance of the Research

This research examines the value of installing additional BDR systems at AF installations, other military installations, or civil airfields worldwide. If this research shows significant bird strike reductions after BDR installation, it will encourage airfields worldwide to install these systems. If the research shows no significant bird strike reductions after BDR installation, it will discourage future purchases of these current avian radar systems.

Statement of the Hypothesis

Utilization of avian radar significantly decreased average aircraft bird strikes per tower operation and average bird strike cost per tower operation *within each* of five AF bases: Dover AFB, Whiteman AFB, Beale AFB, Offutt AFB, and Bagram AB. Additionally, utilization of avian radar significantly decreased average aircraft bird strikes per tower operation and average bird strike costs per tower operation *across* the same five AF bases. Furthermore, *across* bases, bird strike cost avoidance more than offset the total costs of the system over the same time period.

III. Methodology

Research Design Part 1

This research focused on the following airfields which utilize BDRs: Dover AFB, Whiteman AFB, Beale AFB, Offutt AFB, and Bagram AB. The researcher collected all bird strike data and cost data for these airfields from the Air Force Safety Automated System (AFSAS) database after receiving access from the Air Force Safety Center. All aircraft bird strikes at nearby airfields and not on the Air Force base, at altitudes over 3,000 feet, or more than 12 miles off the airfield were eliminated from the tables. This was done in order to isolate bird strikes in which the bird could potentially have been detected by the presence of a BDR system on the airfield under the given system altitude and range limitations advertised by DeTect Inc at http://www.detect-inc.com/.

The researcher calculated, independently by airfield, the bird strike numbers by year using the years beginning 5 years before BDR installation up to 2011. The researcher used 5 years of data prior to installation, isolated by airfield, in order to limit location-based, seasonal, and anomalous variations as much as possible and to limit effects of such trends as increased strike reporting over time. The researcher also chose 5 years since this was the maximum expected data availability for Bagram AB which eventually only provided data for 4 years prior to BDR installation.

The researcher then collected tower operations data for each airfield from the annual USAF Air Traffic Activity Reports (ATARS) provided by the Air Force Flight Standards Agency (AFFSA) located at Tinker AFB, Oklahoma. The researcher calculated bird strikes per tower operation and cost per tower operation in order to normalize these data sets for airfield usage across the years at each airfield. The

researcher chose tower operations as the baseline since this number of operations coincides with the number of times an aircraft was in the BDR range. The tower controls the same airspace the BDR is expected to cover. Once an aircraft leaves this coverage, the pilot transfers away from tower control and over to departure control since the aircraft is no longer considered over the airfield. Total annual values for bird strikes and costs were recorded in tables like example Table 3 below where the bolded red line indicates BDR installation. Some tables include a thin red line indicating BDR system upgrades.

Table 3. Example Data Collection Table

Airfield Name	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Number of Bird Strikes										
Damaging Strikes										
Annual Cost										
Tower Operations										
Strikes/Operation										
Cost/Operation										

The researcher used the two sample t-test (unequal variances) from the Data Analysis package in Microsoft Office Excel 2010 to determine the significance of the differences in means, independently for four of the airfields (excluding Bagram AB), before and after BDR installation for both number of bird strikes per tower operation and annual cost per tower operation reported in tables like example Table 4 below.

Table 4. Example t-Test Results Table

Airfield Name	Before	After
Mean		
Variance		
Observations		
df		
t Stat		
P(T<=t) one-tail		
t Critical one-tail		

Since there is only one year of post installation data for Bagram AB, the researcher used the two sample t-test (equal variances) from the Data Analysis package in Microsoft Office Excel 2010 for Bagram AB.

Each airfield had different n values and different degrees of freedom, but all significance levels were set to $\alpha = 0.05$. The researcher chose $\alpha = 0.05$ to determine with 95% confidence that these results did not occur by chance (McClave, 2001). In this research, significant differences between the means, before and after BDR install, and trend direction were both critical. Therefore, the researcher rejected the null hypothesis for each airfield if the mean value significantly decreased after BDR install. The researcher failed to reject the null hypothesis for each airfield if the means were not significantly different or the mean value statistically increased after BDR installation.

Research Design Part 2

The researcher calculated one number per airfield for average bird strikes per tower operation for the 5 years prior to BDR installation and one number per airfield for average bird strikes per tower operation post BDR installation recorded in a table like example Table 5 below.

Table 5. Example Average Strikes Per Operation Table

Average Strikes/Operation	Before	After
Dover AFB		
Whiteman AFB		
Beale AFB		
Offutt AFB		
Bagram AB		

The researcher then calculated one number per airfield for average cost per tower operation for the 5 years prior to BDR installation and one number per airfield for

average cost per tower operation post BDR installation recorded in a table like example Table 6 below.

Table 6. Example Average Cost Per Operation Table

Average Cost/Operation	Before	After
Dover AFB		
Whiteman AFB		
Beale AFB		
Offutt AFB		
Bagram AB		

The researcher used the paired two samples for means t-test from the Data Analysis package in Microsoft Office Excel 2010 to determine the significance of the differences in means across the five airfields before and across the five airfields after BDR installation for both bird strikes per tower operation and cost per tower operation. These results were reported in tables like example Table 7 below.

Table 7. Example Across Airfields t-Test Results Table

Across Airfields	Before	After
Mean		
Variance		
Observations		
df		
t Stat		
P(T<=t) one-tail		
t Critical one-tail		

Again, each airfield had different n values and different degrees of freedom, but all significance levels were set to $\alpha = 0.05$. The researcher chose $\alpha = 0.05$ to determine with 95% confidence that these results did not occur by chance (McClave, 2001). In this research part 2, significant differences between the means across airfields, before and

after BDR install, and trend direction were both critical. Therefore, the researcher rejected the null hypothesis across airfields if the mean value significantly decreased after BDR install. The researcher failed to reject the null hypothesis across airfields if the means were not significantly different or the mean value increased after BDR installation.

Assumptions and Limitations

The first and most important assumption in this research is that all bird strikes are being properly reported at all Air Force airfields as mandated by AFMAN 91-223. Input into the AFSAS database is limited by whether or not base personnel reported a strike and subsequently entered the data into the system. The researcher also assumed all airfields were at least compliant with the minimum FAA regulations and BASH programs throughout all years studied.

The researcher assumed that the 5-year data collection window prior to BDR installation averaged out anomalies. This time frame was selected before the researcher performed any statistical analysis. For Offutt AFB, this time frame was inclusive of an $8 million incident, the most costly studied in this entire research but it did not skew the final results.

The researcher determined that airfield flight hours were a poor metric for bird strike normalization between bases since some airframes such as the C-5 fly long sortie durations away from airfields and above common bird strike altitudes. The researcher chose tower operations since these operations take place in the same airspace where BDRs are advertised as effective. The researcher acknowledges that the tower's area of

operations and the BDR's range are both somewhat flexible and changing and not always identical and comparing the two could create a small source of error in this research.

This research is limited since tower operations at deployed locations such as Bagram AB were not tracked on ATARS reports until 2008, so the Bagram AB calculations were made without complete data. The small number and relative youth of BDR systems in the Air Force's inventory is another limitation. More systems and more years of accumulated data may have provided slightly different results.

The researcher was unable to account for other changes to BASH programs which potentially occurred at the same time as a BDR install. Any airfield leadership willing to commit to the level of funding to purchase a BDR, might have also instituted other major bird strike corrective methods. These other corrective methods, such as contracting with the USDA or adding a falconry program on the airfield, could have significantly altered the bird strike incidence rates for that airfield. The researcher was unable to isolate multiple simultaneous improvements and their effects on bird strikes.

At the beginning of this effort, the researcher intended to report all data by month in order to isolate the exact time when the BDR was functional at each location. Since bird strikes are random events, many months included a sample size of zero. In order to obtain significant sample sizes, the researcher averaged the data by year. This method provided the proper 6 month ramp-up time determined by DeTect, Inc. for each airfield to collect data over the course of the year of install before collecting post installation data. Unfortunately, this method did not limit each airfield to the exact same ramp-up time.

When calculating the cost of a bird strike, the USAF does not consider any indirect costs such as loss of training or dumped fuel, etc. It was also outside the scope of this research to examine the true cost of lost work time, injury and recovery, or even death of personnel involved in bird strikes. Therefore, the total costs used in this research are much lower than expected total costs reported by a civil airfield for the same strike with the same amount of damage.

This research was also limited since it is impossible determine the potential costs of avoided safety incidents since an avoided incident did not happen and cannot be tracked. Unknown, these radar systems could have potentially avoided an aircraft crash on the level of the E-3 crash in Alaska that killed 24 and resulted in the total loss of an aircraft. One such avoided crash, could have completely changed the results of this research.

The researcher's chosen method of statistical analysis by t test cannot allow for general increases in awareness and reporting of bird strikes or for general increases in bird populations and therefore increases in bird strike risks over time. Future research should include some form of linear regression analysis to account for these changes.

IV. Results

Research Design Part 1

The researcher began by recording all airfield bird strike data in Appendix A, Tables 8-12. The researcher hypothesized that each airfield's average bird strikes per tower operation and average cost per tower operation would decrease after the installation of a BDR at an airfield. All Part 1 t-test results are shown in Tables 13-22.

In observed data for Dover AFB, the bird strike per tower operation mean after installation was significantly different than the bird strike per tower operation mean before installation, but in the wrong direction with bird strikes per tower operation increasing as shown in Appendix A, Table 13. The total cost per tower operation mean after installation was not significantly different than the total cost per tower operation mean before installation so the average cost of bird strikes per tower operation at Dover AFB remained statistically the same as shown in Appendix A, Table 14. There is no evidence to show that the BDR reduced bird strikes per tower operation or costs of damage per tower operation and therefore the researcher failed to reject the null hypothesis with respect to Dover AFB.

In observed data for Whiteman AFB, the bird strike per tower operation mean after installation was significantly different than the bird strike per tower operation mean before installation, but in the wrong direction with bird strikes per tower operation increasing as shown in Appendix A, Table 15. The total cost per tower operation mean after installation was not statistically different than the total cost per tower operation mean before installation so the cost of bird strikes per tower operation at Whiteman AFB

remained statistically the same as shown in Appendix A, Table 16. There is no evidence to show that the BDR reduced bird strikes per tower operation or costs of damage per tower operation and therefore the researcher failed to reject the null hypothesis with respect to Whiteman AFB.

In observed data for Beale AFB, the bird strike per tower operation mean after installation was not significantly different than the bird strike per tower operation mean before installation so the average number of bird strikes per tower operation remained statistically the same as shown in Appendix A, Table 17. The total cost per tower operation mean after installation was significantly different than the total cost per tower operation mean before installation so the cost of bird strikes per tower operation at Beale AFB was statistically reduced as shown in Appendix A, Table 18. There is no evidence to show that the BDR reduced bird strikes per tower operation at Beale AFB. However, there is evidence to show that cost of damage per tower operation was reduced and therefore the researcher rejected the null hypothesis with respect to Beale AFB.

In observed data for Offutt AFB, the bird strike per tower operation mean after installation was not significantly different than the bird strike per tower operation mean before installation so the average number of bird strikes per tower operation remained statistically the same as shown in Appendix A, Table 19. The total cost per tower operation mean after installation was not significantly different than the total cost per tower operation mean before installation so the cost of bird strikes per tower operation at Offutt AFB remained statistically the same as shown in Appendix A, Table 20. There is no evidence to show that the BDR reduced bird strikes per tower operation or costs of

damage per tower operation and therefore the researcher failed to reject the null hypothesis with respect to Offutt AFB.

In observed data for Bagram AB, the bird strike per tower operation mean after installation was not significantly different than the bird strike per tower operation mean before installation so the average number of bird strikes per tower operation remained statistically the same as shown in Appendix A, Table 21. The total cost per tower operation mean after installation was not significantly different than the total cost per tower operation mean before installation so the cost of bird strikes per tower operation at Bagram AB remained statistically the same as shown in Appendix A, Table 22. There is no evidence to show that the BDR reduced bird strikes per tower operation or costs of damage per tower operation and therefore the researcher failed to reject the null hypothesis with respect to Bagram AB.

Research Design Part 2

The researcher began by averaging all airfield bird strike data across bases as shown in Appendix A, Tables 23-24. The researcher hypothesized that across airfield average bird strikes per tower operation and across airfield average cost per tower operation would decrease after the installation of a BDR at an airfield. All Part 2 t-test results are shown in Tables 25-26.

In observed data across the five bases, the bird strike per tower operation mean after installation was significantly different than the bird strike per tower operation mean before installation, but in the wrong direction with bird strikes per tower operation increasing as shown in Appendix A, Table 25. The total cost per tower operation mean

after installation across the 5 bases was not significantly different than the total cost per tower operation mean before installation so the cost of bird strikes per tower operation across bases remained statistically the same as shown in Appendix A, Table 26. There is no evidence to show that the BDR reduced bird strikes or costs of damage across the five bases and therefore the researcher failed to reject the null hypothesis.

V. Conclusions/Recommendations

Conclusions

Using AFSAS cost data, these specific airfields, and the time frame studied, the researcher concluded that only one airfield benefited from the installed BDR system. Beale AFB, the successful base, had the same average number of bird strikes per tower operation, but reduced average strike costs to almost zero over the 3-year period since installation. Barring other base related interventions that were not identified in this study, it appears that this system led to a reduction in cost per strike to almost zero. Across the years prior to install, Beale AFB averaged $85,945 per year spent on bird strike repairs. The BDR system cost over the time since installation, is estimated at $117,267 per year. Even with incredible mitigation results, the system at Beale is still losing $31,322 per year. From a purely financial perspective, looking at this data for Beale AFB during this time period, it would have been more cost effective to allow the bird strikes and pay the lower cost of repairs rather than spending the time and money installing and maintaining this BDR.

The total purchase cost of all 5 systems was $2,303,469. Total estimated maintenance and upkeep costs for the different years at the different bases totals $315,725. To date, the estimated total system cost is $2,619,194 with a current cost per year of $805,275. Again, looking at cost alone, four bases were a complete loss but Beale AFB had the estimated $85,945 in cost avoidance. In aggregate, the Air Force has already lost $2,533,249 and is losing approximately $719,330 per year on these existing systems

Fortunately, Beale AFB has been recognized as a great example of how this system can be applied successfully and many important lessons have been learned. The most important lesson is that senior leadership support is essential at a base attempting this level of technological advancement. Placement of the system, communication methods, certificates of operation, and many other lessons were also learned. It is expected that future experimentation will follow this positive trend.

It is important to remember that the Air Force costing structure for bird strike damage only includes direct costs as mentioned earlier and these costs are often totaled during the initial estimation process and not after the repairs are completed. It is safe to say that the Air Force cost method significantly underestimates the total cost of bird strike damage including many hidden costs such as lost revenue, costs for placing aircrew and passengers in hotels, re-scheduling aircraft, flight cancellations, lost training, crew shuffling, passenger frustrations, and dumped fuel for emergency landings (Cleary & Dolbeer, 2005).

Also remember, the Air Force Safety Center reports 39 aircraft destroyed and 33 deaths on record since 1973 (Center, Air Force Safety, 2012). This research was solely focused on utilizing existing Air Force cost data to determine the cost efficiencies of these systems but future studies should consider such hidden costs as listed above and, more importantly, the potential loss of human life from allowing these strikes to continue. Although not cost effective, experimenting with these systems is providing critical information for the development of the future technology which may one day eliminate damaging or lethal aircraft bird strikes.

Recommendations

With ever increasing military drawdowns, Air Force base-level safety offices are less manned and stretched in several directions by many competing safety programs of which BASH sometimes seems least urgent. The Air Force should establish USDA BASH contracts on every airfield preferably rolled up into one contract at the Air Force Safety Center for volume pricing and standardization.

If the Air Force decides to purchase any future BDRs, they should be sourced through the Air Force Safety Center for volume pricing and standardization. This budget should also be provided at the Air Force level rather than the current funding by each wing-level commander so the Air Force Safety Center can prioritize which airfield has the highest bird strike risk. With a consolidated budget at the Air Force Safety Center, quantity funds will be available to place major purchases like BDRs in significantly less time.

The Air Force should ardently pursue new and emerging bird strike technologies. Since the introduction of BASH, bird abatement ideas flat-lined until the recent efforts to produce ground BDR systems. Major technology movements should immediately be evaluated for potential BASH utilization. The researcher suggests ongoing experimentation with these existing BDRs while simultaneously pursuing advancements in airborne bird radar systems for real time pilot updates.

Advancing technologies utilizing directed energy have incredible potential for both ground-based and eventually aircraft-based BASH systems. One company, Oceanit, is currently developing a ground-based directed energy system capable of causing

immediate avian discomfort. Edwards AFB, California, has begun researching these technologies through Technology International, Inc. with a small grant of $100,000 (See Appendix B for solicitation information and Appendix C for award information). Imagine a ground based airfield system that can create uncomfortable regions at approach and departure with controlled beams of directed energy. With no long-term ill-health effects, the birds immediately feel uncomfortable, flying away for more habitable environments.

Take this thinking one step further and picture a small on-aircraft system that scans and recognizes threats out in front of the aircraft. This active system could then direct energy at the speed of light out in front of the aircraft and towards the bird heating its skin and forcing its wings closer to the body eliminating lift and immediately dropping the bird below the flight path of the oncoming aircraft. Once the plane passes safely by, the directed energy stops and the bird spreads its wings and resumes flight with no negative long-term health effects. This active response system might prevent aircraft damage and loss of human life while saving the lives of many protected species of animals currently killed in aircraft bird strikes (Scott & Robie, 2009).

Other tests, being conducted with ultraviolet light, look promising. Unlike humans, birds can see in the ultraviolet spectrum. Some specialists believe that this trait allows them to see special plumage for such events as mating rituals. Studies utilizing ultraviolet light or leading edge tape ultraviolet reflectivity should begin immediately. While these ideas might sound far-fetched, this technology is just over the horizon and this type of research must receive immediate funding to ever be plausible.

Until these future systems exist, the Air Force's focus should be on 100% aircraft bird strike reporting with all airfields complying with existing BASH program guidelines since all existing literature shows major reductions in bird activity and therefore bird strikes at compliant locations.

Future research should be conducted on these BDR systems using linear regression to account for increased reporting and increased risk due to increasing bird populations through time. These future studies will have the added benefit of even more years of data on which to base conclusions.

It is important to remember that a true aircraft avoidance system could end bird strikes and potentially save the aviation industry losses of life and over $2 billion every year.

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Appendix A. Tables

Table 8. Dover AFB Bird Strike Data

Dover AFB	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Number of Bird Strikes	54	19	36	21	28	34	57	51	49	45
Damaging Strikes	3	2	2	3	0	4	3	1	5	2
Annual Cost	$25,138	$9,830	$1,000,997	$2,418,797	$0	$3,648,013	$74,032	$992,679	$54,687	$394,990
Tower Operations	39,174	37,773	33,290	35,478	29,276	31,431	33,638	34,833	38,133	34,812
Strikes/Operation	0.0013785	0.000503	0.0010814	0.0005919	0.0009564	0.0010817	0.0016945	0.0014641	0.001285	0.0012927
Cost/Operation	$0.64	$0.26	$30.07	$68.18	$0.00	$116.06	$2.20	$28.50	$1.43	$11.35

Table 9. Whiteman AFB Bird Strike Data

Whiteman AFB	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Number of Bird Strikes	41	17	14	56	88	92	85	63	87
Damaging Strikes	2	0	4	3	1	4	5	4	5
Annual Cost	$5,481	$0	$332,868	$86,002	$4,540	$20,473	$215,659	$39,926	$195,554
Tower Operations	20,785	22,753	25,249	28,406	34,954	35,218	29,528	31,241	21,638
Strikes/Operation	0.0019726	0.0007472	0.0005545	0.0019714	0.0025176	0.0026123	0.0028786	0.0020166	0.0040207
Cost/Operation	$0.26	$0.00	$13.18	$3.03	$0.13	$0.58	$7.30	$1.28	$9.04

Table 10. Beale AFB Bird Strike Data

Beale AFB	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Number of Bird Strikes	15	20	25	28	10	9	21	20
Damaging Strikes	6	1	2	4	2	1	0	0
Annual Cost	$166,123	$3,410	$111,874	$130,440	$17,877	451	0	0
Tower Operations	41,012	32,590	43,468	40,667	34,892	32,483	34,348	37,002
Strikes/Operation	0.0003657	0.0006137	0.0005751	0.0006885	0.0002866	0.0002771	0.0006114	0.0005405
Cost/Operation	$4.05	$0.10	$2.57	$3.21	$0.51	$0.01	$0.00	$0.00

Table 11. Offutt AFB Bird Strike Data

Offutt AFB	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Number of Bird Strikes	40	82	19	96	77	64	92	67
Damaging Strikes	1	2	1	7	5	3	2	0
Annual Cost	$10,000	$8,115,981	$83,330	$75,769	$73,148	$60,373	$236,646	$0
Tower Operations	32,409	32,226	21,314	28,104	28,425	25,897	23,492	23,779
Strikes/Operation	0.0012342	0.0025445	0.0008914	0.0034159	0.0027089	0.0024713	0.0039162	0.0028176
Cost/Operation	$0.31	$251.85	$3.91	$2.70	$2.57	$2.33	$10.07	$0.00

Table 12. Bagram AB Bird Strike Data

Bagram AB	FY06	FY07	FY08	FY09	FY10	FY11
Number of Bird Strikes	N/A	61	93	166	205	252
Damaging Strikes	N/A	4	4	7	4	17
Annual Cost	N/A	$1,438,354	$8,074	$692,293	$60,887	$434,440
Tower Operations	N/A	N/A	105,827	152,454	187,984	228,550
Strikes/Operation	N/A	N/A	0.0008788	0.0010889	0.0010905	0.0011026
Cost/Operation	N/A	N/A	$0.08	$4.54	$0.32	$1.90

Table 13. Dover AFB Strikes Per Operation t-Test Results

Dover AFB	Before	After
Mean	0.00090224	0.0013636
Variance	1.2938E-07	5.257E-08
Observations	5	5
df	7	
t Stat	-2.4185401	
P(T<=t) one-tail	0.02309554	
t Critical one-tail	1.89457861	

Table 14. Dover AFB Cost Per Operation t-Test Results

Dover AFB	Before	After
Mean	19.8296634	31.908748
Variance	896.675324	2331.9603
Observations	5	5
df	7	
t Stat	-0.4753456	
P(T<=t) one-tail	0.32450775	
t Critical one-tail	1.89457861	

Table 15. Whiteman AFB Strikes Per Operation t-Test Results

Whiteman AFB	Before	After
Mean	0.00155264	0.0028821
Variance	7.32E-07	7.061E-07
Observations	5	4
df	7	
t Stat	-2.3394048	
P(T<=t) one-tail	0.0259452	
t Critical one-tail	1.89457861	

Table 16. Whiteman AFB Cost Per Operation t-Test Results

Whiteman AFB	Before	After
Mean	3.32091956	4.5500978
Variance	31.9781546	18.05876
Observations	5	4
df	7	
t Stat	-0.3721312	
P(T<=t) one-tail	0.36040264	
t Critical one-tail	1.89457861	

Table 17. Beale AFB Strikes Per Operation t-Test Results

Beale AFB	Before	After
Mean	0.0005059	0.0004763
Variance	2.937E-08	3.103E-08
Observations	5	3
df	4	
t Stat	0.2325335	
P(T<=t) one-tail	0.4137685	
t Critical one-tail	2.1318468	

Table 18. Beale AFB Cost Per Operation t-Test Results

Beale AFB	Before	After
Mean	2.089761	0.0046281
Variance	2.9393497	6.426E-05
Observations	5	3
df	4	
t Stat	2.7194758	
P(T<=t) one-tail	0.0265078	
t Critical one-tail	2.1318468	

Table 19. Offutt AFB Strikes Per Operation t-Test Results

Offutt AFB	Before	After
Mean	0.00215899	0.0030684
Variance	1.1232E-06	5.691E-07
Observations	5	3
df	6	
t Stat	-1.4127931	
P(T<=t) one-tail	0.10371442	
t Critical one-tail	1.94318028	

Table 20. Offutt AFB Cost Per Operation t-Test Results

Offutt AFB	Before	After
Mean	52.266666	4.1349152
Variance	12449.132	27.80855
Observations	5	3
df	4	
t Stat	0.9628091	
P(T<=t) one-tail	0.1950831	
t Critical one-tail	2.1318468	

Table 21. Bagram AB Strikes Per Operation t-Test Results

Bagram AFB	Before	After
Mean	0.00101939	0.0011026
Variance	1.4826E-08	
Observations	3	1
df	2	
t Stat	-0.5918646	
P(T<=t) one-tail	0.30696751	
t Critical one-tail	2.91998558	

Table 22. Bagram AB Cost Per Operation t-Test Results

Bagram AFB	Before	After
Mean	1.64706163	1.9008532
Variance	6.29646846	
Observations	3	1
df	2	
t Stat	-0.087591	
P(T<=t) one-tail	0.46909114	
t Critical one-tail	2.91998558	

Table 23. Across Airfields Average Strikes Per Operation

Average Strikes/Operation	Before	After
Dover AFB	0.000902	0.001364
Whiteman AFB	0.001553	0.002882
Beale AFB	0.000506	0.000476
Offutt AFB	0.002159	0.003068
Bagram AB	0.001019	0.001103

Table 24. Across Airfields Average Cost Per Operation

Average Cost/Operation	Before	After
Dover AFB	$19.83	$31.91
Whiteman AFB	$3.32	$4.55
Beale AFB	$2.09	$0.00
Offutt AFB	$52.27	$4.13
Bagram AB	$1.65	$1.90

Table 25. Across Airfields Bird Strikes Per Operation t-Test Results

Across Bases	Before	After
Mean	0.00122784	0.0017786
Variance	4.1079E-07	1.302E-06
Observations	5	5
df	4	
t Stat	-2.1616147	
P(T<=t) one-tail	0.04835698	
t Critical one-tail	2.13184679	

Table 26. Across Airfields Cost Per Operation t-Test Results

Across Bases	Before	After
Mean	15.8308143	8.4998484
Variance	472.513731	174.58631
Observations	5	5
df	4	
t Stat	0.69901553	
P(T<=t) one-tail	0.26152674	
t Critical one-tail	2.13184679	

Appendix B. Directed Energy Solicitation Information

SITIS Archives - Topic Details

Program:	SBIR
Topic Num:	AF093-224 (AirForce)
Title:	Non-Lethal Avian Active Denial System Using Directed Energy
Research & Technical Areas:	Materials/Processes, Biomedical, Weapons

Objective: Research and develop a non-lethal system that uses directed energy as a form of deterrence to repel birds in critical areas around aircraft and other high value systems. (Must not require a permit)

Description: The primary purpose of this system is collision avoidance between aircraft and birds. A secondary purpose for this technology would be to prevent other forms of damage caused by birds nesting or perching in unwanted areas. The Sikes Act and Air Force Instruction (AFI) 32-7064 require the Department of Defense (DoD) to manage the natural resources of each military reservation within the United States and to provide sustained multiple uses of those resources. Edwards AFB complies with these requirements by preparation and implementation of an Integrated Natural Resources Management Plan (INRMP). The primary purpose of the INRMP is to use adaptive ecosystem management strategies to protect the properties and values of the base's natural environment in concert with the military mission. This is accomplished by defining and implementing natural resource management goals and objectives that collectively achieve habitat and species sustainability; thereby, ensuring no net loss in the capability of the installation's lands with a realistic testing and training environment. One of the major goals of the INRMP is Goal 10: Improve Integration of Natural Resources Management and Ecosystem Strategies with Other Base Organizations Consistent with the Military Mission and Goal 12: Conserve Migratory Birds and their Habitat. These goals can be achieved through the implementation of management strategies to conserve/protect migratory birds in concert with other base organizations, and their programs and plans while ensuring no net loss to the capability of the military mission. The BASH (Bird/Wildlife Air Strike Hazard) Program at Edwards AFB is a prime example of implementing ecosystem management strategies. Every year bird-strikes to aircraft, both military and civilian, cause millions of dollars of damage and in some instances, loss of human life. Additionally, damage in and around facilities and aircraft where birds nest and

congregate costs millions of dollars in the man-hours needed for bird prevention and clean-up. A cost effective system is needed to effectively repel birds away from areas that could result in aircraft/facility damage. The military has been actively engaged in the research, development, and deployment of Active Denial Systems (ADS) designed for human crowd control. This system uses microwave radiation as a deterrent. The technological challenge is to detect birds flying into an area where there is the potential for collision with an aircraft then effectively repelling the birds using a non-lethal form of directed energy. Finally, the frequency used for this system must not interfere with any current operational aircraft or ground-based sensor systems and it must not be able to target personnel.

PHASE I: Define the proposed concept and develop key component technological milestones. Provide a detailed analysis of the predicted performance. Determine the technical feasibility of a prototype device.

PHASE II: Develop and successfully demonstrate a working prototype system based upon the Phase I results. Provide a plan for practical laboratory testing with eventual field deployment.

PHASE III / DUAL USE: MILITARY APPLICATION: Leads to the design and installation of a non-lethal avian active denial system for use at military facilities that have high concentrations of birds that pose a threat of aircraft or facility damage. COMMERCIAL APPLICATION: Leads to the design and installation of a non-lethal avian active denial system for use at airports that have high concentrations of birds that pose a threat of aircraft or facility damage.

References: National Council on Radiation Protection and Measurements (NCRP) Publication No. 86, No. 119. 2. Department of Defense Instruction (DODI) 6055.11, Protection of DoD Personnel from Exposure to Radiation and Military Exempt Lasers. 3. Sikes Act Improvement Amendments of 1997, as amended (Title 16 United States Code [U.S.C.] 670). 4. Air Force Instruction (AFI) 32-7064, Integrated Natural Resources Management. 5. Integrated Natural Resources Management Plan for Edwards Air Force Base, California (95th Air Base Wing, 2008).

Keywords: Electromagnetic radiation, radiation, microwave radiation, active denial, bird-strikes, collision avoidance, non-lethal, sensors, wavelength

Appendix C. Directed Energy Award Information

Non-Lethal Avian Active Denial System Using Directed Energy

Award Information

Agency: **Department of Defense**	Branch: **Air Force**	Award ID: **97548**	Program Year/Program: **2010 / SBIR**
Agency Tracking Number: **F093-224-2496**	Solicitation Year: **N/A**	Solicitation Topic Code: **AF 09-224**	Solicitation Number: **N/A**

Small Business Information

TECHNOLOGY INTERNATIONAL, INC.

429 West Airline Highway Suite S LaPlace, LA 70068

View profile »

Woman-Owned:Yes

Minority-Owned:No

HUBZone-Owned:No

Phase 1

Fiscal Year:2010

Title:Non-Lethal Avian Active Denial System Using Directed Energy

Agency/Branch:DOD / USAF

Contract:FA9302-10-M-0011

Award Amount:$100,000.00

Abstract:

This Phase I SBIR Project is aimed at determination of the technical feasibility and commercial viability of an Avian Infrasound Detection (passive) and Denial (active and

non-lethal) System (AVIDDS) using infrasound energy. The primary purpose of the AVIDDS is system is collision avoidance between aircraft and birds during daily flight operations without impacting mission requirements through detection and denial actions. Those actions have the side benefit of preventing other forms of damage caused by birds nesting and perching in unwanted areas. The AVIDDS meets the technological challenge of detecting birds flying into an area where there is the potential for collision with an aircraft using a passive infrasound capability for detection of their presence then using non-lethal active infrasound capability to effectively repel the birds. The infrasound frequency range will not interfere with any current operational aircraft or ground-based sensor systems and it must not be able to target personnel. BENEFIT: The AVIDDS developed for military aircrafts can be used as a non-lethal avian active denial system at commercial aviation facilities, towers, and energy wind-driven windmills that have high concentrations of birds in areas that pose a threat to aircraft from bird-strikes and/or aircraft/facility damage.

Appendix D. Quad Chart

Avian Radar – Is It Worth The Cost?

The AFIT of Today is the Air Force of Tomorrow.

Major Robert F. Ehasz
Department of Operational Sciences (ENS)

ADVISOR
Dr. William Cunningham

Research Focus:

- Bird Detection Radar (BDR) Results
  - 5 avian radar systems in USAF inventory
    - Dover AFB
    - Whiteman AFB
    - Beale AFB
    - Offutt AFB
    - Bagram AB
  - Business Case Analysis (BCA)

Methodology: Delphi Study

- Research Design Part 1
  - Baseline each base using tower operations
  - Compare averages before and after BDR with t-tests
- Research Design Part 2
  - Baseline across 5 bases using tower operations
  - Compare averages before and after with t-tests

Results:

Base	Average Bird Strikes per Tower Operation	Average Cost per Tower Operation
Dover AFB	Increased	Same
Whiteman AFB	Increased	Same
Beale AFB	Same	Decreased
Offutt AFB	Same	Same
Bagram AB	Same	Same
Across Bases	Increased	Same

Recommendations:

- Maximize bird strike reporting
- All AF airfields need to follow BASH plans
- AF Safety Center should control BASH budget
- Continue experiments with existing BDRs
- Stop purchasing additional BDRs until development of see-and-avoid capability
- Pursue future methods of bird strike deterrence, such as directed energy and ultraviolet light

Sponsor:
Dr. Steven Butler
AFMC/CA

Appendix E. Vita

Vita

Major Ehasz earned his commission in 2000 as a graduate of the U.S. Air Force Academy, Colorado Springs, Colorado. He is a logistician with a core background in aircraft maintenance. As an aircraft maintenance officer, he has served in a variety of sortie production roles including Fixed Wing OIC Balad AB, Iraq in support of Operation IRAQI FREEDOM in 2007. Major Ehasz is a fully qualified acquisitions officer with experience at the depot level having earned his Level II Program Management Certification while participating in the Acquisitions and Logistics Experience Exchange Tour (ALEET) program. Prior to his current assignment, he was Commander, 354th Maintenance Squadron, Eielson AFB, AK, where he was responsible for the organization and training of 325 Airmen. He also directed all off-equipment maintenance and ammunition support for 21 F-16 aggressor aircraft supporting RED FLAG Alaska while executing an $825K budget. His next assignment is Commander, 3rd Aircraft Maintenance Squadron, Joint Base Elmendorf-Richardson, AK. He is married to the former Sharon Fitzgerald and has two sons, Blane and Kale.

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14. ABSTRACT
Major Ehasz explored the correlations between bird strike data at United States Air Force (USAF) airfields prior to Avian Radar installation and post Avian Radar installation in order to perform a Business Case Analysis (BCA) to help guide future potential purchases of Avian Radar. He defined the scope of the bird strike problem, explained the associated costs, explored current mitigation efforts leading up to Avian Radar, performed statistical analysis of USAF airfield strike data, and finally suggested additional future solutions for further research. Major Ehasz recommended that all airfields (both civilian and military) recommit to the application of current Air Force Bird/Wildlife Aircraft Safety Hazard (BASH) and Federal Aviation Administration (FAA) guidance in order to obtain proven bird population and bird strike reductions. As a result of this research, Major Ehasz has concluded that existing Avian Radar is not a cost effective method of bird strike reduction, but the USAF should continue to use existing systems for experimentation and collection of further data in order to continue to pursue the technological breakthroughs of tomorrow.

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